DSTO

AR-010-398

Evaluation of the Performance of a Minehunting Sonar

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Maritime Operations Division
Aeronautical and Maritime Research Laboratory

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ABSTRACT

A methodology to measure the detection and classification performance of a minehunting sonar is outlined. A technique for specifying the detection and classification performance in a contract and then relating that to the performance measured in sea trials is described. The report also shows how a model can be used to adjust the required performance to allow for the effects of the environment.

RELEASE LIMITATION

Approved for public release

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Published by

DSTO Aeronautical and Maritime Research Laboratory
PO Box 4331
Melbourne Victoria 3001 Australia

Telephone: (03) 9626 7000
Fax: (03) 9626 7999

AR-010-398
December 1997

APPROVED FOR PUBLIC RELEASE

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Executive Summary

The performance of mine hunting sonars fluctuates with the environment, with target characteristics and with operator skill. Because of the variability the sonar performance cannot be reliably evaluated by a single measurement but must be determined as a statistical sampling problem.

The detection performance can be assessed by conducting many detection runs at various target aspects and generating probability of detection curves and confidence limits from the results. These data can then be compared to the specified performance.

In practice the environmental conditions inevitably deviate from the ideal, are never as specified and usually degrade sonar performance. The influence of the environment can be allowed for by using a sonar performance prediction model, which takes into account the prevailing conditions, to scale the specified detection range and using the range so scaled as the range to be demonstrated.

In a similar sampling process the classification performance of a minehunting sonar can be evaluated by determining probabilities of correct classification against a range of mine like and non-mine objects.

Contents

1. Introduction

This report summarises three aspects of minehunting sonar performance:

a) It describes a trials methodology to measure detection and classification performance.

b) It shows how the detection and classification performance can be specified in a contract and related to the performance measured in (a).

c) It shows how a model of the sonar can be used to allow for the various environments encountered during sea trials.

Detection performance is measured by the probability of detection (Pd) as a function of range. Classification performance is determined by measuring two separate probabilities, the probability of correctly classifying a mine as a mine and the probability of correctly classifying a non-mine as a non-mine. The report shows how confidence limits for each of the measured probabilities can be obtained. The classification performance is measured by requiring the operator to classify a series of objects either as mines or non-mines.

The methodology described here was used successfully during trials of RAN minehunters. These procedures have been jointly developed by the RAN and the Maritime Operations Division of DSTO.

2. Factors Affecting Detection Performance

During trials and exercises it is apparent that the detection performance of a minehunting sonar fluctuates from ping-to-ping. Variations are also observed over longer periods and these variations occur even when the environment appears to be constant. Because the sonar performance fluctuates, the measurement of performance must be treated as a statistical sampling process. It is not sufficient to carry out a single detection run against a target and to use the detection range as a reliable indicator of sonar detection performance. The detection performance of a minehunting sonar is dependent on several factors, each of which fluctuates independently. These factors include:

1. Bottom Reverberation. The area of the bottom that is generating reverberation will change from ping-to-ping. This will cause the level of the reverberation background to vary. Similar considerations will apply for surface and volume reverberation.

2. Noise. The noise level against which the echo must be detected may depend either on the ship's own self noise due to hydrodynamic flow or machinery noise, or on ambient noise in the ocean. These noise sources are independent and will vary with time.

3. Propagation Loss. Propagation loss between the sonar transducer and the mine will vary due to microstructure in the water. As the mine-hunter moves through the water the target will be insonified by slightly different transmission paths. This will cause fluctuations in propagation from ping-to-ping.
4. Target strength. The target strength of a typical mine varies with aspect over a dynamic range of approximately 20dB, and variations of 5 to 10 dB over aspect changes of only a few degrees are typical. As the mine-hunter closes the target the aspect will usually vary slightly from ping-to-ping and the target strength will fluctuate.
5. Operator. The ability of the operator to detect targets (i.e. the detection threshold) will vary with time due to the state of alertness, fatigue and sea sickness. There will also be variation between operators due to different skill levels.

By taking appropriate steps the combined effect of each of these variations can be minimised, but not entirely eliminated.

3. Specification of Detection Performance

The measure of detection performance used is that of probability of detection as a function of range. This is defined as the probability of detection by the time that the minehunter has closed the range from infinity to the given range. This statement of detection performance is only valid for one particular environment and target. The state of operator alertness must also be stated.

4. Measurement of Probability of Detection

The method of measuring the probability of detection as a function of range is now described. On each run the minehunter commences at a sufficient range to be out of contact with the mine. The range is closed until a detection is made by the operator, the range is noted and the minehunter then breaks off contact and opens the range for another run. The detection range is measured for a number of approaches to the mine. Several types of detection can be made; if the position of the mine is known to the operator the target is said to be indicated. This will be the best detection performance that can be expected of the sonar. If the operator is unaware of the position of the mine the target is said to be unindicated. This is closer to the operational situation but in all such controlled trials there is a reasonable degree of operator alertness. In an evaluation it is recommended to proceed from the first stage in which indicated targets are used to the second stage using unindicated targets. The final stage should be a free play exercise in which the minehunter is tasked to clear a given area of mines. This will give a measure of the area clearance rate which is an important operational measure of effectiveness.

Consider now the measurement of probability of detection versus range for indicated detections of a single mine. As an example, 20 detection runs are carried out over a period of a few hours, the environment is monitored and determined to be constant, thus the measured detection performance will consist of the set of 20 ranges. Table 1 shows a typical set of detection ranges. It is quite common to find a variation of a factor of 2 between the maximum and minimum ranges. If no detection is made during a run, zero range should be logged. In order to calculate the probability as a function of range, the ranges are ranked, with the shortest range at the top of the column. A probability of 1/n, where n is the number of runs carried out, is assigned to the detection at the longest range. In this case since n=20 a probability of 1/20=0.05 is assigned to the detection at the longest range. For each successive reduction in detection range in the column the Pd in incremented by 0.05. Thus the Pd for the shortest range detection is equal to 1.0. For the example given, Pd=0.05 at a range of 507 m and Pd=1 at a range of 157 m, ie all mines will have been detected by the time the range closes to 157 m.

Table 1. Typical Detection Ranges and Estimated Probabilities of Detection.

Run Number	Detection Range (m)		Ranked Detection Ranges	Probability of Detection	90% Confidence Limits Lower	Upper
1	319		157	1.00	0.861	1.000
2	253		217	0.95	0.784	0.997
3	270		230	0.90	0.717	0.982
4	312		253	0.85	0.656	0.958
5	359		270	0.80	0.599	0.929
6	157		298	0.75	0.544	0.896
7	217		312	0.70	0.492	0.860
8	230		318	0.65	0.442	0.823
9	351		319	0.60	0.394	0.783
10	450		328	0.55	0.347	0.741
11	431		341	0.50	0.302	0.698
12	507		351	0.45	0.259	0.653
13	389		359	0.40	0.217	0.606
14	421		378	0.35	0.177	0.558
15	378		389	0.30	0.140	0.508
16	409		409	0.25	0.104	0.456
17	341		421	0.20	0.071	0.401
18	328		431	0.15	0.042	0.344
19	318		450	0.10	0.018	0.283
20	298		507	0.05	0.003	0.216

5. Confidence Intervals

Sonar performance measurement is a statistical sampling process. Therefore it is not sufficient in this example to simply state that Pd=0.9 at a range of 230m. It is necessary to construct an interval about the Pd and with a specified confidence state that the Pd lies in the interval. For a 90% confidence interval, the statement will be correct 90% of the time, in the sense that if we repeated the experiment many times and computed Pd and the corresponding confidence interval for each of them, in about 90 cases out of every 100 the result would contain Pd. The basic distribution is binomial and the confidence limits are tabulated in Table 21 and charts 2, 3 and 4 of Crow, Davis & Maxfield [1]. The two sided limits should be used, but this section of Table 21 in Crow Davis and Maxfield contains several errors and should not be used. The one-sided limit section of Table 21 has been checked and is correct. The one-sided limit can be used to derive the 90% two-sided limit by taking the 95% value from the table as the upper limit. The lower limit is obtained by entering Table 21 with n and n-r and subtracting the table entry from 1. For example if n=20 and r=18, i.e. a Pd=0.9, the upper 95% one-sided limit is 0.982. The lower 95% one-sided limit is given by entering table 21 with n=20 and n-r=2. This gives a value of 1-0.283=0.717. Therefore the measured Pd=0.9 and the 90% two-sided confidence limits are 0.717 and 0.982. The 90% two-sided limits for values of n up to 30 have been obtained by this method and are tabulated in the Appendix. A copy of Chart II which gives confidence limits for larger n is also included in the Appendix.

Note that there is no connection between the Pd=0.9 value and the 90% confidence intervals, other values of Pd and confidence limits could have been chosen.

It is important to consider the number of runs to be carried out. If the number is small the confidence interval is wide. As the number of runs increases the interval reduces. The following table shows how the upper and lower confidence limits vary as the number of runs increases. Values are shown for Pds of 0.9 and 0.5.

This table is plotted in figure 1. It shows clearly that for small n the confidence intervals are large. For example, if only 2 runs are carried out the detection range for Pd=0.5 can be measured, however the confidence limits on the Pd at that range are 0.025 and 0.975. If 250 runs are carried out the limits become 0.45 and 0.55. A Law of Diminishing Returns is operating and it is generally considered that about 25 runs gives a suitable balance between an acceptable confidence interval and cost.

Table 2. Number of Runs and Confidence Intervals.

Number of Runs	Pd=0.5 CL lower	Pd=0.5 CL upper	Pd=0.9 CL lower	Pd=0.9 CL upper
2	0.025	0.975		
4	0.098	0.902		
6	0.153	0.847		
8	0.193	0.807		
10	0.222	0.778	0.606	0.995
16	0.279	0.721		
20	0.302	0.698	0.717	0.982
26	0.327	0.673		
30	0.339	0.661	0.761	0.972
50	0.380	0.620	0.820	0.960
100	0.420	0.580	0.840	0.940
250	0.450	0.550	0.870	0.930

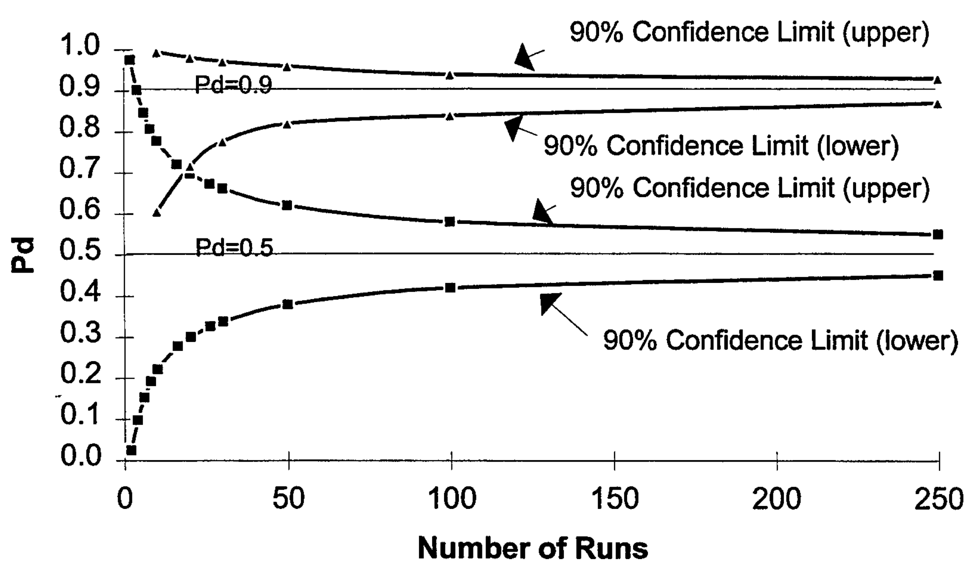


Figure 1. 90% Confidence limits vs. Number of runs.

The upper and lower 90% confidence limits for the example data are shown in table 1 and are plotted in figure 2. This figure shows the area within which the 90% confidence limits fall. The figure can be interpreted two ways, for a given range it shows the confidence limits on the probability of detection. Alternatively for a given probability of detection it shows a range interval over which that Pd applies with a 90% confidence. This example shows that the Pd=0.9 at a range of 230 m, but when the 90% confidence limits are considered then the upper confidence limit is 300 m. Since 20 detections out of 20 runs (ie Pd=1.0) gives a lower 90% confidence limit of 0.861 it is not possible to state a lower range at which that Pd applies.

Section 2.3.3 of Crow, Davis & Maxfield gives a numerical solution for the confidence limits which is valid for large samples. It is approximately true for the sample sizes encountered in sonar evaluations but can lead to values of Pd just greater than 1 or just less than 0. It is therefore recommended that the exact tabulated values be used.

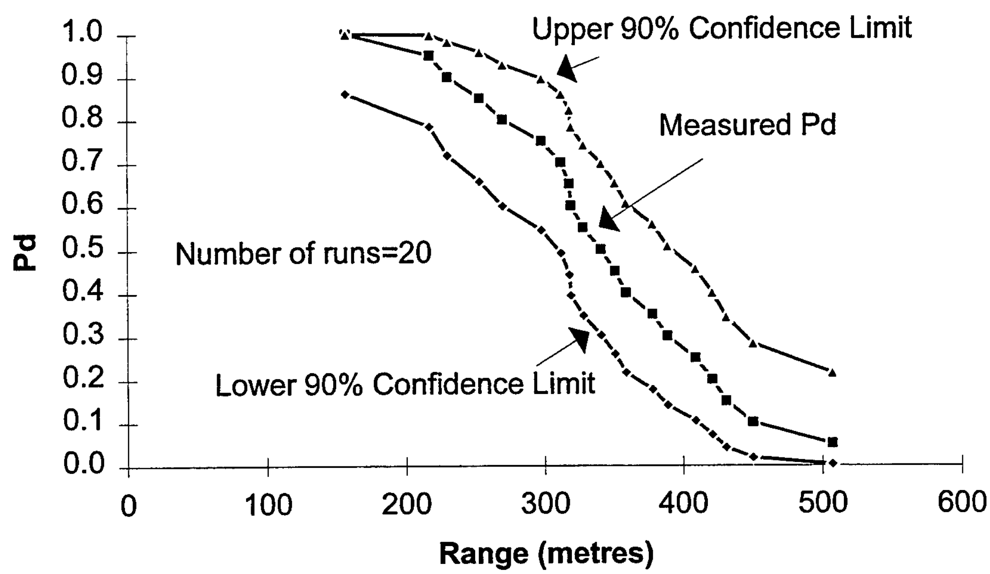


Figure 2. Typical minehunting sonar performance.

6. Specification of Performance to be Demonstrated

A contract between the sonar supplier and the client Navy should state that the sonar will achieve detection at a given range with a given probability of detection. This performance will be achieved in a given set of environmental conditions against a target of a specified target strength and with a specified state of operator alertness.

The environmental conditions would include sound speed profile, water temperature, bottom type, wind speed, noise level, Pd and probability of false alarm (Pfa) .

In general the environmental conditions prevailing during the sonar trials will be different to those specified in the contract and will influence the detection performance. For example a strongly negative sound speed profile may severely limit the region of the bottom that the sonar can insonify, and therefore limit the possible detection range. Obviously some method must be used to compensate for this type of situation and to ensure that neither side in the contract is disadvantaged.

7. Use of Sonar Model to Obtain Predicted Performance

A sonar model is used to predict the performance of the minehunting sonar. The model and its algorithms need to be agreed between the Navy and the Sonar Contractor. The inputs needed to run the model include:

a. Environment

Sound speed profile
Water temperature
Absorption
Wind speed
Bottom type or measured values of bottom
Backscatter strength
Noise levels (ambient, flow, machinery)
Volume scatter strength

b. Sonar

Source level
Beam patterns (vertical & horizontal, transmit and receive)
Frequency
Pulse length
Type of transmission
Sector width
Vertical beams and tilt
Processing gains
Transducer depth or trail back (if VDS)

c. Target

Target strength
Dimensions

The model uses these inputs to calculate the ratio of the echo to the noise as function of range. The Receiver Operating Characteristic (ROC) is used to obtain the S/N for detection for a given value of Pd and Pfa. Typically Pd=0.9 and Pfa=0.0001 give a

S/N=+12 dB. Some relaxation in the S/N may be made in the case of unindicated detections.

During the trial the environment is regularly monitored and the model is used to calculate the predicted sonar performance. The point corresponding to the predicted range and Pd is plotted on the measured Pd curve. Several possible outcomes are shown in figure 3.

In fig 3a the measured performance is better than predicted since the predicted detection range falls to the left of the lower confidence limit curve. The sonar therefore satisfies the requirement of the performance specification.

In fig 3b the predicted point falls between the upper and lower confidence limits. The measurements indicate that there is a 90% chance that the detection range for the given Pd lies between the upper and the lower confidence limits. In this case there is some statistical uncertainty that the required performance has been met. As it will be difficult to resolve this uncertainty one way or the other, the performance will be considered to have passed. If however the predicted point falls to the right of the upper confidence limit curve as in fig 3c the sonar has failed to meet the requirement of the performance specification. This procedure is valid only if the environment remains constant during the trial.

If there are significant changes in the environment during the trial, then for each detection range there will be a corresponding predicted range. Thus the trial will generate a set of pairs of values which need to be tested to determine whether the measured values are better or worse than those calculated by the model. A suitable test is the Wilcoxon Signed Ranks Test which is described in Siegel & Castellan [2].

8. Specification of Classification Performance

Classification is the process in which, once a mine like contact is detected, the operator determines with a high confidence whether it is a mine or a non-mine. If the contact is classified as a mine, it will be further investigated either by a ROV or a diver. If it is classified a non-mine no further action is required. The operator uses characteristics of the echo such as shape, length, variation with aspect and shadow to classify.

As the object is either a mine or a non-mine, and the operator can classify as a mine or non-mine, there are 4 outcomes which constitute a decision matrix.

Table 3. Classification decision matrix.

	OBJECT IS	
CLASSIFY AS	MINE	NON-MINE
MINE	Pccm	1-Pccnm
NON-MINE	1-Pccm	Pccnm

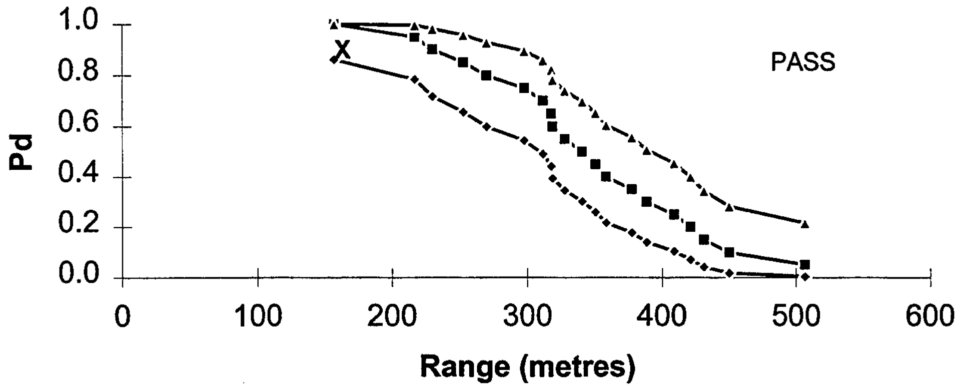


Figure 3A. Predicted range less than measured range.

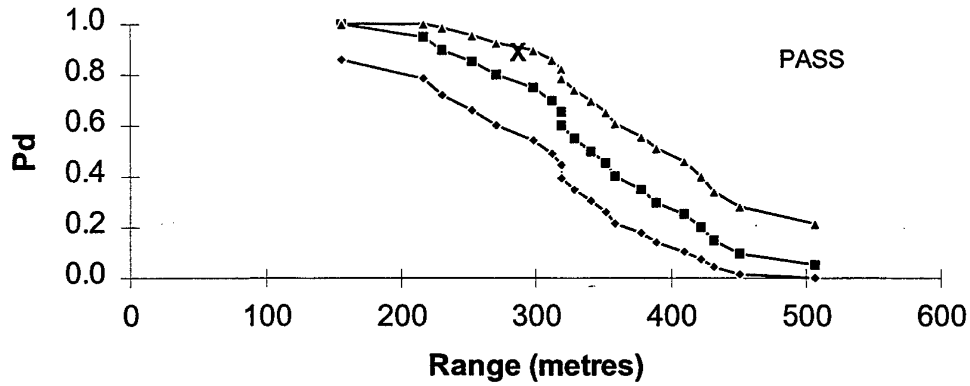


Figure 3B. Predicted range greater than measured range but less than upper limit.

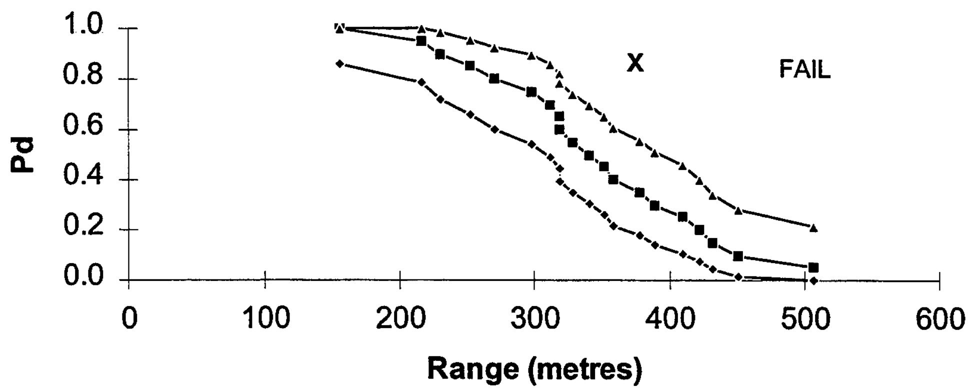


Figure 3C. Predicted range greater than upper confidence limit.

Figure 3. Comparison between measured and specified performance.

If the object is a mine then the probability of correctly classifying it as a mine is Pccm. If the object is a mine and is incorrectly classified as a non-mine the associated probability is 1-Pccm. Similarly if the object is a non-mine then the probability of correctly classifying it as a non-mine is Pccnm The probability of classifying a non-mine as a mine is 1-Pccnm. There is a different penalty associated with each of these wrong decisions. If a non-mine is classified as a mine, time is wasted in the investigation. However, if a mine is classified as a non-mine the minehunter and other ships may be placed at risk.

The classification performance to be satisfied is specified by these two probabilities, Pccm and Pccnm.

9. Measurement of Classification Performance

Classification performance is determined by approaching an object until a detection is made. The operator is then free to manoeuvre the ship to vary the aspect and to approach to a minimum range, corresponding to the safety range. The operator is then required to classify as either a mine or a non-mine. If the object is a mine then Pccm is given by the number of correct classifications divided by the number of approaches made to the mine. For example, if 25 approaches were made to a mine and the operator classified it as a mine on 20 occasions the Pccm=20/25=0.8. Similarly if the object is a non- mine then Pccnm is given by the number of correct classifications divided by the number of approaches made to the non-mine.

In order to measure classification performance a number of mines and non-mines are laid. The mines and non-mines should be encountered at random so that no pattern is discernible to the operator. The features of the non-mines should be carefully selected to enable the classification sonar to distinguish them from mines. For example the mines could consist of two cylindrical ground mines (length=2.0m, diameter=0.5m) and (length=1.5m, diameter=0.3m) and a moored mine with cable and sinker. The non-mines could consist of a fluid filled target sphere of diameter 15cm, a length of free flooding cylindrical water pipe with end caps (length 3.0m, diameter 0.5m) and an approximately spherical rock of diameter 0.6m. The operators would be briefed on the nature of the threat mines before the trial. The sphere should be distinguishable from the mines because of its size. Similarly the classification sonar should be able to measure the length of the pipe and classify it as a non-mine. The shape of the rock plus any shadow should enable it to be classified as a non-mine.

It is important to have approximately equal numbers of mines and non-mines. If there are 9 mines and 1 non-mine then by classifying everything as a mine Pccm would be estimated to be 0.9, an apparent good result.

In a similar manner to the detection performance calculations confidence limits can be obtained. If 25 runs are carried out then the following table shows Pccm, n the number of correct classifications and the upper and lower 90% confidence limits.

Table 4. 90% Confidence limits for n correct classifications in 25 instances.

n	Pccm	CLlower	CLupper
19	0.76	0.610	0.892
20	0.8	0.638	0.899
21	0.84	0.693	0.929
22	0.88	0.745	0.955
23	0.92	0.786	0.979
24	0.96	0.841	0.996
25	1.00	0.898	1.000

In order to not rule out a Pccm of 0.9 then there must be at least 20 correct classifications out of 25.

10. Conclusion

A methodology has been described which enables the detection and classification performance of a minehunting sonar to be rigorously measured. Confidence limits can also be placed on the measurements. A method of using a computer model to allow for the effects of the environment is also described. The procedures are suitable for use as contract acceptance trials.

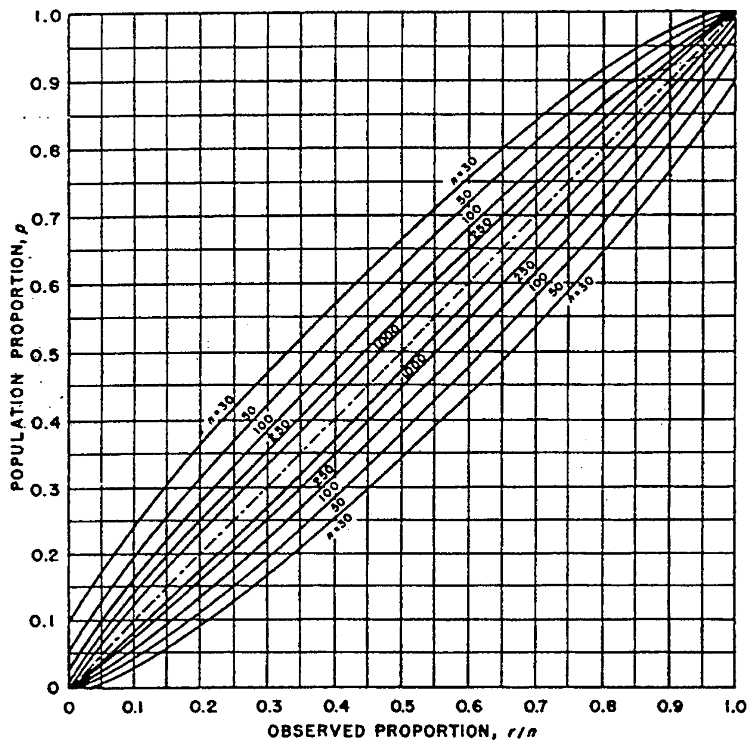
11. References

1. Crow, E. L., F.A. Davis and M.W. Maxfield. *Statistics Manual.* Dover 1960.

2. Siegel, S. and N.J. Castellan. *Parameter Statistics for the Behavioural Sciences.* McGraw Hill, 1988.

Appendix

CHART II. 90% CONFIDENCE BELTS FOR PROPORTIONS *



* Use explained in Sec. 2.3.3a. Table 21 should be used for sample size $n \leq 30$. It gives the interval explicitly for each sample size. This chart was adapted with permission from W. J. Dixon and F. J. Massey, Jr., *Introduction to Statistical Analysis*, New York, McGraw-Hill, 1951, p. 320.

Fig A1. 90% Confidence limits for a proportion for n>30.
(Extract from Crow, Davis and Maxfield)

Table A1. 90% Confidence Limits for a Proportion.
(Calculated from one-sided limits tabulated in Crow, Davis and Maxfield, p262)

90% CONFIDENCE LIMITS

	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
r	n=2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9
0	0.000	0.776	0.000	0.632	0.000	0.527	0.000	0.451	0.000	0.393	0.000	0.348	0.000	0.312	0.000	0.283
1	0.025	0.975	0.017	0.865	0.013	0.751	0.010	0.657	0.009	0.582	0.007	0.521	0.006	0.471	0.006	0.429
2	0.224	1.000	0.135	0.983	0.098	0.902	0.076	0.811	0.063	0.729	0.053	0.659	0.046	0.600	0.041	0.550
3			0.368	1.000	0.249	0.987	0.189	0.924	0.153	0.847	0.129	0.775	0.111	0.711	0.098	0.655
4					0.473	1.000	0.343	0.990	0.271	0.937	0.225	0.871	0.193	0.807	0.169	0.749
5							0.549	1.000	0.418	0.991	0.341	0.947	0.289	0.889	0.251	0.831
6									0.607	1.000	0.479	0.993	0.400	0.954	0.345	0.902
7											0.652	1.000	0.529	0.994	0.450	0.959
8													0.688	1.000	0.571	0.994
9															0.717	1.000

Table A1. 90% Confidence Limits for a Proportion (continued).

90% CONFIDENCE LIMITS

	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
r	n=10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17
0	0.000	0.259	0.000	0.238	0.000	0.221	0.000	0.206	0.000	0.193	0.000	0.181	0.000	0.171	0.000	0.162
1	0.005	0.394	0.005	0.364	0.004	0.339	0.004	0.316	0.004	0.297	0.003	0.279	0.003	0.264	0.003	0.250
2	0.037	0.507	0.033	0.470	0.030	0.438	0.028	0.410	0.026	0.385	0.024	0.363	0.023	0.344	0.021	0.326
3	0.087	0.607	0.079	0.564	0.072	0.527	0.066	0.495	0.061	0.466	0.057	0.440	0.053	0.417	0.050	0.396
4	0.150	0.696	0.135	0.650	0.123	0.609	0.113	0.573	0.104	0.540	0.097	0.511	0.090	0.484	0.085	0.461
5	0.222	0.778	0.200	0.729	0.181	0.685	0.166	0.645	0.153	0.610	0.142	0.577	0.132	0.548	0.124	0.522
6	0.304	0.850	0.271	0.800	0.245	0.755	0.224	0.713	0.206	0.675	0.191	0.640	0.176	0.609	0.166	0.580
7	0.393	0.913	0.350	0.865	0.315	0.819	0.287	0.776	0.264	0.736	0.244	0.700	0.227	0.667	0.212	0.636
8	0.493	0.963	0.436	0.921	0.391	0.877	0.355	0.834	0.325	0.794	0.300	0.756	0.279	0.721	0.260	0.689
9	0.606	0.995	0.530	0.967	0.473	0.928	0.427	0.887	0.390	0.847	0.360	0.809	0.333	0.773	0.311	0.740
10	0.741	1.000	0.636	0.995	0.562	0.970	0.505	0.934	0.460	0.896	0.423	0.858	0.391	0.822	0.364	0.788
11			0.762	1.000	0.661	0.996	0.590	0.972	0.534	0.939	0.489	0.903	0.452	0.868	0.420	0.834
12					0.779	1.000	0.684	0.996	0.615	0.974	0.560	0.943	0.516	0.910	0.478	0.876
13							0.794	1.000	0.703	0.996	0.637	0.976	0.583	0.947	0.539	0.915
14									0.807	1.000	0.721	0.997	0.656	0.977	0.604	0.950
15											0.819	1.000	0.736	0.997	0.674	0.978
16													0.829	1.000	0.750	0.997
17															0.838	1.000

Table A1. 90% Confidence Limits for a Proportion (continued).

90% CONFIDENCE LIMITS

	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
r	**18**	**18**	**19**	**19**	**20**	**20**	**21**	**21**	**22**	**22**	**23**	**23**	**24**	**24**	**25**	**25**
0	0.000	0.153	0.000	0.146	0.000	0.139	0.000	0.133	0.000	0.127	0.000	0.122	0.000	0.117	0.000	0.113
1	0.003	0.238	0.003	0.226	0.003	0.216	0.002	0.207	0.002	0.198	0.002	0.190	0.002	0.183	0.002	0.176
2	0.020	0.310	0.019	0.296	0.018	0.283	0.017	0.271	0.016	0.259	0.016	0.249	0.015	0.240	0.014	0.231
3	0.047	0.377	0.044	0.359	0.042	0.344	0.040	0.329	0.038	0.316	0.037	0.304	0.035	0.292	0.034	0.282
4	0.080	0.439	0.075	0.419	0.071	0.401	0.068	0.384	0.065	0.369	0.062	0.355	0.059	0.342	0.057	0.330
5	0.116	0.498	0.110	0.476	0.104	0.456	0.099	0.437	0.094	0.420	0.090	0.404	0.086	0.389	0.082	0.375
6	0.156	0.554	0.147	0.530	0.140	0.508	0.132	0.487	0.126	0.468	0.120	0.451	0.115	0.435	0.110	0.420
7	0.199	0.608	0.188	0.582	0.177	0.558	0.168	0.536	0.160	0.515	0.152	0.496	0.146	0.479	0.139	0.462
8	0.244	0.659	0.230	0.632	0.217	0.606	0.206	0.583	0.196	0.561	0.186	0.540	0.178	0.521	0.170	0.504
9	0.291	0.709	0.274	0.680	0.259	0.653	0.245	0.628	0.233	0.605	0.222	0.583	0.212	0.563	0.202	0.544
10	0.341	0.756	0.320	0.726	0.302	0.698	0.286	0.672	0.271	0.647	0.258	0.625	0.248	0.603	0.236	0.583
11	0.392	0.801	0.368	0.770	0.347	0.741	0.328	0.714	0.311	0.689	0.296	0.665	0.282	0.642	0.270	0.621
12	0.446	0.844	0.418	0.812	0.394	0.783	0.372	0.755	0.353	0.729	0.335	0.704	0.319	0.681	0.305	0.659
13	0.502	0.884	0.470	0.853	0.442	0.823	0.417	0.794	0.395	0.767	0.375	0.742	0.358	0.718	0.341	0.695
14	0.561	0.920	0.524	0.890	0.492	0.860	0.464	0.832	0.439	0.804	0.417	0.778	0.397	0.752	0.379	0.730
15	0.623	0.953	0.581	0.925	0.544	0.896	0.513	0.868	0.485	0.840	0.460	0.814	0.437	0.788	0.417	0.764
16	0.690	0.980	0.641	0.956	0.599	0.929	0.563	0.901	0.532	0.874	0.504	0.848	0.479	0.822	0.456	0.798
17	0.762	0.997	0.704	0.981	0.656	0.958	0.616	0.932	0.580	0.906	0.549	0.880	0.521	0.854	0.496	0.830
18	0.847	1.000	0.774	0.997	0.717	0.982	0.671	0.960	0.631	0.935	0.596	0.910	0.565	0.885	0.538	0.861
19			0.854	1.000	0.784	0.997	0.729	0.983	0.684	0.962	0.645	0.938	0.611	0.914	0.580	0.890
20					0.861	1.000	0.793	0.998	0.741	0.984	0.696	0.963	0.658	0.941	0.625	0.918
21							0.867	1.000	0.802	0.998	0.751	0.984	0.708	0.965	0.670	0.943
22									0.873	1.000	0.820	0.998	0.760	0.985	0.718	0.966
23											0.878	1.000	0.817	0.998	0.769	0.986
24													0.883	1.000	0.824	0.998
25															0.887	1.000

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J.L. Thompson & M.J. Bell

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DOCUMENT CONTROL DATA

1. PRIVACY MARKING/CAVEAT (OF DOCUMENT)

2. TITLE Evaluation of the Performance of a Minehunting Sonar	3. SECURITY CLASSIFICATION (FOR UNCLASSIFIED REPORTS THAT ARE LIMITED RELEASE USE (L) NEXT TO DOCUMENT CLASSIFICATION) Document (U) Title (U) Abstract (U)
4. AUTHOR(S) J.L. Thompson and M.J. Bell	5. CORPORATE AUTHOR Aeronautical and Maritime Research Laboratory PO Box 4331 Melbourne Vic 3001 Australia

6a. DSTO NUMBER	6b. AR NUMBER	6c. TYPE OF REPORT	7. DOCUMENT DATE
DSTO-TN-0123	AR-010-398	Technical Note	December 1997

8. FILE NUMBER	9. TASK NUMBER	10. TASK SPONSOR	11. NO. OF PAGES	12. NO. OF REFERENCES
G6 4/8-4619	NAV 95/290	MHCPD	16	2

13. DOWNGRADING/DELIMITING INSTRUCTIONS	14. RELEASE AUTHORITY
None	Chief, Maritime Operations Division

15. SECONDARY RELEASE STATEMENT OF THIS DOCUMENT

Approved for public release

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16. DELIBERATE ANNOUNCEMENT

No Limitations

17. CASUAL ANNOUNCEMENT Yes

18. DEFTEST DESCRIPTORS

MineHunting Sonar, Detection, Classification, Sonar prediction model, Statistics

19. ABSTRACT
A methodology to measure the detection and classification performance of a minehunting sonar is outlined. A technique for specifying the detection and classification performance in a contract and then relating that to the performance measured in sea trials is described. The report also shows how a model can be used to adjust the required performance to allow for the effects of the environment.